11: Crafting Reports

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LESSON OBJECTIVES

1. Describe the purpose of using R Markdown as a communication and workflow tool
2. Incorporate Markdown syntax into documents
3. Communicate the process and findings of an analysis session in the style of a report

USE OF R STUDIO & R MARKDOWN SO FAR...

1. Write code
2. Document that code
3. Generate PDFs of code and its outputs
4. Integrate with Git/GitHub for version control

BASIC R MARKDOWN DOCUMENT STRUCTURE

1. **YAML Header** surrounded by — on top and bottom
    - YAML templates include options for html, pdf, word, markdown, and interactive
    - More information on formatting the YAML header can be found in the cheat sheet
2. **R Code Chunks** surrounded by "`on top and bottom  + Create using`Cmd/Ctrl+Alt+I'
    - Can be named {r name} to facilitate navigation and autoreferencing
    - Chunk options allow for flexibility when the code runs and when the document is knitted
3. **Text** with formatting options for readability in knitted document

RESOURCES

Handy cheat sheets for R markdown can be found: here, and here.

There's also a quick reference available via the `Help→Markdown Quick Reference` menu.

Lastly, this website give a great & thorough overview.

THE KNITTING PROCESS

- The knitting sequence 

- Knitting commands in code chunks:
- `include = FALSE` - code is run, but neither code nor results appear in knitted file
- `echo = FALSE` - code not included in knitted file, but results are
- `eval = FALSE` - code is not run in the knitted file
- `message = FALSE` - messages do not appear in knitted file
- `warning = FALSE` - warnings do not appear...
- `fig.cap = "..."` - adds a caption to graphical results

WHAT ELSE CAN R MARKDOWN DO?

See: https://rmarkdown.rstudio.com and class recording. * Languages other than R... * Various outputs...

WHY R MARKDOWN?

<Fill in our discussion below with bullet points. Use italics and bold for emphasis (hint: use the cheat sheets or `Help` →`Markdown Quick Reference` to figure out how to make bold and italic text).>

- Creates easily *communicable* output that can use **figures, code, and/or text** to build a report
- Keeps your script *organized*
- Multiple output formats and opportunities for **creativity**
- Separate chunks have **flexible** options
- Easy to use and conducive to *collaboration*

TEXT EDITING CHALLENGE

Create a table below that details the example datasets we have been using in class. The first column should contain the names of the datasets and the second column should include some relevant information about the datasets. (Hint: use the cheat sheets to figure out how to make a table in Rmd)

File Name	Description
ECOTOX_Neonicotinoids_Insects_raw.csv	EPA: Neonicotinoids and their effects on insects
EPAair_O3_NC2018_raw.csv	EPA: Air quality monitoring of ozone in North Carolina in 2018
EPAair_O3_NC2019_raw.csv	EPA: Air quality monitoring of ozone in North Carolina in 2019
EPAair_PM25_NC2018_raw.csv	EPA: Air quality monitoring of PM2.5 in North Carolina in 2018
EPAair_PM25_NC2019_raw.csv	EPA: Air quality monitoring of PM2.5 in North Carolina in 2019
EPAair_O3_GaringerNC2010_raw.csv - EPAair_O3_GaringerNC2019_raw.csv	EPA: O3 concentrations at Garinger High School in North Carolina from 2010-2019
NEON_NIWO_Litter_massdata_2018-08_raw.csv	Litterfal and Fine Woody Debris sampled in 2018

File Name	Description
NTL-LTER_Lake_ChemistryPhysics_Raw.csv	Physical & chemical data for several lakes in the North Temperate Lakes District in Wisconsin, USA
NTL-LTER_Lake_Nutrients_Raw.csv	Nutrient measurements for several lakes in the North Temperate Lakes District in Wisconsin, USA
NTL-LTER_Lake_Carbon_Raw.csv	Carbon data for several lakes in the North Temperate Lakes District in Wisconsin, USA
NWIS_SiteFlowData_NE_RAW.csv	USGS: National Water Information System flow data
NWIS_SiteInfo_NE_Raw.csv	USGS: location and general info about groundwater, surface water, and meteorological sites in USA

R CHUNK EDITING CHALLENGE

Installing packages

Create an R chunk below that installs the package `knitr`. Instead of commenting out the code, customize the chunk options such that the code is not evaluated (i.e., not run).

```
install.packages("knitr")
```

Setup

Create an R chunk below called "setup" that checks your working directory, loads the packages `tidyverse`, `lubridate`, and `knitr`, and sets a ggplot theme. Remember that you need to disable R throwing a message, which contains a check mark that cannot be knitted.

Load the NTL-LTER_Lake_Nutrients_Raw dataset, display the head of the dataset, and set the date column to a date format.

Customize the chunk options such that the code is run but is not displayed in the final document.

Data Exploration, Wrangling, and Visualization

Create an R chunk below to create a processed dataset do the following operations:

- Include all columns except lakeid, depth_id, and comments
- Include only surface samples (depth = 0 m)
- Drop rows with missing data

```
#processing the data
nutrient.data.proc <- nutrient.data.raw %>%
  select(lakename, year4, daynum, sampledate, depth, tn_ug, tp_ug, nh34, no23, po4) %>%
    filter(depth==0) %>%
      drop_na()
```

Create a second R chunk to create a summary dataset with the mean, minimum, maximum, and standard deviation of total nitrogen concentrations for each lake. Create a second summary dataset that is identical

except that it evaluates total phosphorus. Customize the chunk options such that the code is run but not displayed in the final document.

Create a third R chunk that uses the function `kable` in the knitr package to display two tables: one for the summary dataframe for total N and one for the summary dataframe of total P. Use the `caption = " "` code within that function to title your tables. Customize the chunk options such that the final table is displayed but not the code used to generate the table.

Table 2: Summary of surface total nitrogen (N) concentrations for each lake

lakename	mean_tn_ug	min_tn_ug	max_tn_ug	sd_tn_ug
Central Long Lake	690.0469	343.020	953.063	209.09341
Crampton Lake	362.6813	353.380	376.304	12.05748
East Long Lake	810.7834	380.620	2608.956	335.41457
Hummingbird Lake	1036.6695	779.053	1221.960	204.36889
Paul Lake	368.7564	45.670	628.625	106.34741
Peter Lake	561.8752	219.720	2048.151	305.64909
Tuesday Lake	423.5605	237.363	554.418	78.84522
West Long Lake	762.6017	303.170	2870.302	402.95992

Table 3: Summary of surface total phosphorous (P) concentrations for each lake

lakename	mean_tp_ug	min_tp_ug	max_tp_ug	sd_tp_ug
Central Long Lake	21.70981	8.190	37.270	7.076388
Crampton Lake	11.16033	5.803	15.555	4.946759
East Long Lake	29.28984	8.000	101.050	17.375710
Hummingbird Lake	36.21925	32.765	42.119	4.146717
Paul Lake	10.45606	1.222	36.070	4.805142
Peter Lake	18.39153	0.000	64.383	10.976205
Tuesday Lake	11.71853	6.325	18.663	3.044289
West Long Lake	19.82981	2.690	63.243	10.541276

Create a fourth and fifth R chunk that generates two plots (one in each chunk): one for total N over time with different colors for each lake, and one with the same setup but for total P. Decide which geom option will be appropriate for your purpose, and select a color palette that is visually pleasing and accessible. Customize the chunk options such that the final figures are displayed but not the code used to generate the figures. In addition, customize the chunk options such that the figures are aligned on the left side of the page. Lastly, add a fig.cap chunk option to add a caption (title) to your plot that will display underneath the figure.

Communicating results

Write a paragraph describing your findings from the R coding challenge above. This should be geared toward an educated audience but one that is not necessarily familiar with the dataset. Then insert a horizontal rule below the paragraph. Below the horizontal rule, write another paragraph describing the next steps you might take in analyzing this dataset. What questions might you be able to answer, and what analyses would you conduct to answer those questions?

The data investigated in the above coding challenge are nutrient measurements for several lakes in the North Temperate Lakes District in Wisconsin, USA. These data were collected at a Long Term Ecological Research station established by the National Science Foundation. The data contain physical and chemical

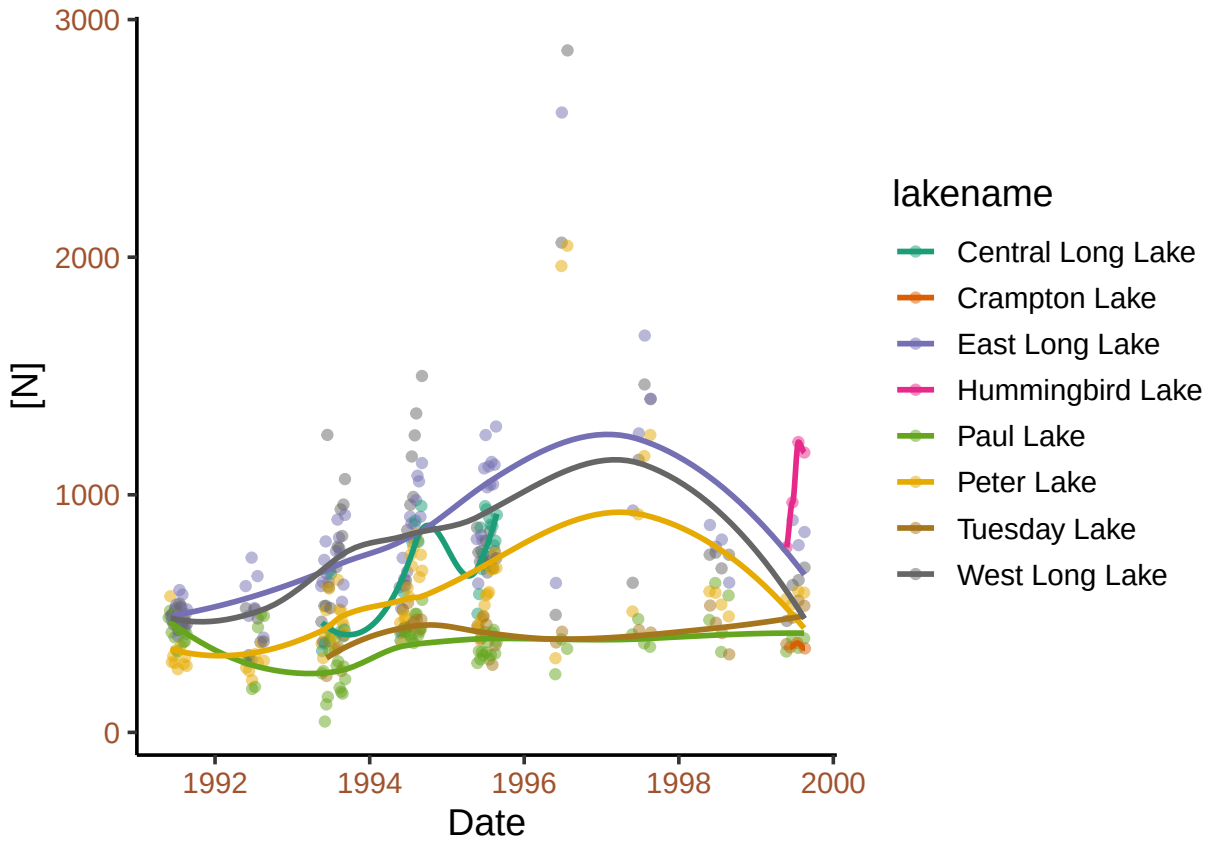

Figure 1: Total surface N over time in each lake

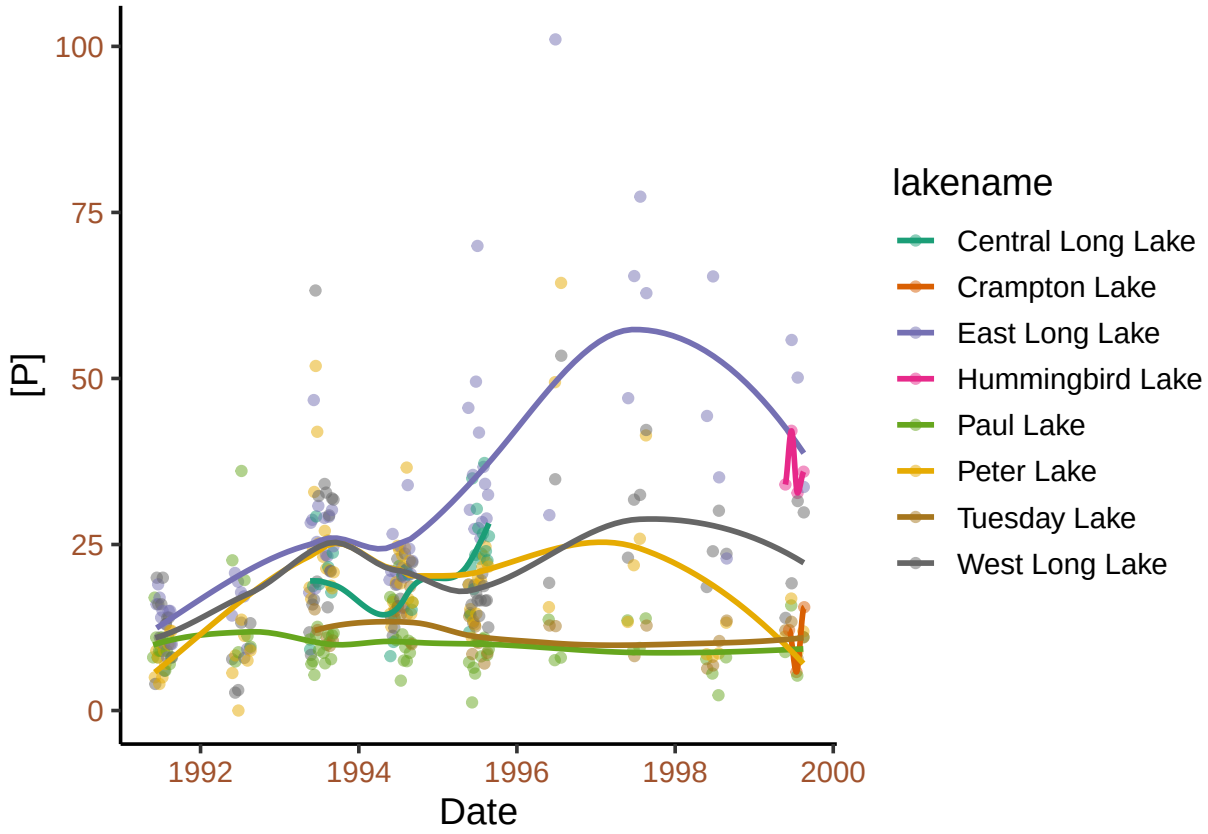

Figure 2: Total surface P over time in each lake

variable measurements, including nutrient concentrations. This report shows that Paul Lake had the lowest average concentrations of *both* nitrogen (N) and phosphorous (P) at the surface, and Hummingbird Lake had the highest average concentrations of *both* elements at the surface (Table 2 and 3). However, data for Hummingbird lake are only available in the final year. East Long Lake had the highest surface N and P concentrations for the vast majority of the time frame (Figure 1 and 2). Although with some variation, the general patterns of decreases/increases in surface nutrient concentrations across the years are reflected in both N and P, indicating that they may be correlated in some way.

With further analysis of these data, we can answer questions surrounding significant differences between nutrient concentrations over lakes at a given point in time or across time. To test the difference between concentrations of two lakes at a given time, a simple t-test can be used. However, to analyze across time, a time series analysis could be carried out with these data to detect seasonality and determine if N and P concentrations have changed over time across different lakes. Additionally, these analyses can be replicated for different depths and compared against each other to see if similar findings and patterns are found across all depths.

KNIT YOUR PDF

When you have completed the above steps, try knitting your PDF to see if all of the formatting options you specified turned out as planned. This may take some troubleshooting.

OTHER R MARKDOWN CUSTOMIZATION OPTIONS

We have covered the basics in class today, but R Markdown offers many customization options. A word of caution: customizing templates will often require more interaction with LaTeX and installations on your computer, so be ready to troubleshoot issues.

Customization options for pdf output include:

- Table of contents
- Number sections
- Control default size of figures
- Citations
- Template (more info here)

pdf_document:
toc: true
number_sections: true
fig_height: 3
fig_width: 4
citation_package: natbib
template: